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VARIATIONS OF COLIFORM BACTERIA AND OTHER POLLUTION INDICES IN SURFACE WATERS

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Despite continuing sewage treatment plant construction, New York Harbor has had a 10% annual increase in coliform pollution since the early 1950's. It is suggested that this increase might be due to an "aftergrowth" of the organisms in the receiving waters stimulated by nutrients such as phosphate or nitrogen compounds in secondary treatment effluent. Using data on various streams with improved waste systems a study was made to determine whether similar coliform density increases were occurring and if they could be correlated with phosphate, detergent, or other pollution parameters.

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Water Quality Section
Basic Data Branch
Division of Water Supply and Pollution Control
Public Health Service
Department of Health, Education, and Welfare

April 14, 1965

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UNITED STATES GOVERNMENT
MEMORANDUM

PUBLIC HEALTH SERVICE
1014 Broadway
Cincinnati, Ohio 45202

TO : Paul DeFalco, Jr., Director
Hudson-Champlain & Metropolitan Coastal Comprehensive
Water Pollution Control Project, PHS, Metuchen, New Jersey

April 14, 1965

FROM : A. W. Breidenbach, Acting Chief
Water Quality Section, Basic Data Branch, DWSPC

SUBJECT: Report, "Variations of Coliform Bacteria and Other Pollution Indices in Surface Waters."

In response to your telephoned request of March 26, 1965, I am forwarding an evaluation of selected PHS Water Pollution Surveillance System data. This report has been prepared by Messrs. Gunnerson and Winter to assist you in evaluating the implications of an average 10 per cent annual increase in coliform pollution in New York Harbor during a period when a number of sewage treatment facilities have been constructed and placed in operation.

Comparisons of pollution indices between locations which are not similar hydrologically are limited in applicability. On the other hand, we may expect that correlations between coliform populations and other parameters at a particular station can be explained in terms of local conditions.

You will note that the final portion of the report is addressed to the specific question of increasing coliforms in New York Harbor. Comparison with field and laboratory work in southern California coastal waters in which Mr. Gunnerson participated indicates that such increases may be expected when improved treatment, but not effluent chlorination, is provided.

A. W. Breidenbach

Attachment

cc: R. S. Green (2)
Region II
J. A. Winter
C. G. Gunnerson

CGG:rd

VARIATIONS OF COLIFORM BACTERIA

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OTHER POLLUTION INDICES IN SURFACE WATERS

April 14, 1965

Introduction

The City of New York has been monitoring coliform levels in the New York Harbor area, using MPN techniques, for many years. In recent years, there has been a continuing program of sewage treatment plant construction. Despite these improvements, coliform pollution has reportedly shown an annual increase of 10 per cent per year since the early 1950's.

In attempting to explain these results, it has been suggested that this annual ten per cent increase in coliform concentrations might be due to an "aftergrowth" of the organisms in the receiving waters stimulated by nutrients such as phosphate or nitrogen compounds in secondary treatment effluent. It has also been speculated that there has been a more complete break-up of bacterial clumps because of increased levels of surface-active materials in the water which would raise the MPN levels accordingly.

Historical data are available from Water Pollution Surveillance System stations throughout the United States. Many of the cities on these streams have improved waste treatment programs of relatively recent origin. An attempt was accordingly made to determine whether similar coliform density increases were occurring, and whether they could be correlated with phosphate, detergent, or other pollution parameters.

Methods

Criteria for station selection included a recent and marked increase in coliform levels, an essentially complete record for at least 5 years, and geographic variability. The following five stations were selected for study:

Number of Years Data Available	Station Number	Location	River
6	14	Buffalo, New York	Lake Erie
6	18	Poughkeepsie, New York	Hudson
7	27	Lock & Dam No. 3 below Minneapolis, St. Paul	Mississippi
7	29	Kansas City, Kansas	Missouri
5	74	Philadelphia, Pa.	Schuylkill

The STORET System was used for retrieval and manipulation of the required data for this study.

Coliform data were compared with BOD, COD, 24-hour chlorine demand, percent oxygen saturation, and phosphate in order to determine the presence or absence of correlations or supporting trends. Because of the limited record lengths, ABS data were not included in the study. All parameters were stated in terms of yearly means for the water years on record. Coliform data were expressed in terms of yearly geometric means because of the exponential reproduction rate of bacteria; other parameters are expressed as arithmetic means. The yearly means were plotted for each parameter for the years of record, station by station. A visual comparison was made between coliform data and all other measurements to identify positive, negative, and zero correlation.

Results

Graphs 1 through 5 show the levels of seven parameters at each station as yearly arithmetic or geometric means. The horizontal dashed line through each parameter curve indicates the overall arithmetic mean of that parameter for the period of record.

It must be emphasized that the scales of measurement have been expanded or contracted for each station to display the numerical change of each parameter as broadly as possible. Consequently,

comparisons between either levels or rates of change in pollution indices cannot be made. For example, the coliform increase at Buffalo is depicted as large graphically as was the change at station #27 - Lock and Dam #3, which was in reality some 400 times as great.

A conclusion of the correlative data over the entire period of record is summarized by station below:

WPSS Station #14 - Lake Erie at Buffalo, N. Y.

Increasing Trend	Decreasing Trend	No Trend Indicated
BOD		
COD	Per Cent Oxygen	Phosphate
Coliform Density	Saturation	Chlorine Demand

No correlation of parameters with stream flow.

WPSS Station #18 - Hudson River below Poughkeepsie, N. Y.

Increasing Trend	No Trend Indicated
COD	BOD
Chlorine Demand	Per Cent Oxygen
Coliform Density	Saturation

There was a high degree of correlation between coliform values and flows in water years 1959-1962.

WPSS Station #27 - Mississippi River Lock & Dam #3 below St. Paul, Minn.

Slight Increasing Trend	Decreasing Trend	No Trend Indicated
COD		
Chlorine Demand	Per Cent Oxygen	BOD
Coliform Density	Saturation	Phosphate

Stream flow correlates well with coliform values.

WPSS Station #29 - Missouri River at Kansas City, Kan.

Increasing Trend	Decreasing Trend	No Trend Indicated
BOD	Chlorine Demand	COD
Phosphate		Per Cent Oxygen Saturation
Coliform Density		

Stream flow correlates partially with coliform values.

WPSS Station #74 - Schuylkill River at Philadelphia, Pa.

Increasing Trend	Decreasing Trend	No Trend Indicated
COD		BOD
Chlorine Demand	Per Cent Oxygen Saturation	
Phosphate		
Coliform Density		

Stream flow correlates negatively with coliform densities.

Discussion

As might be expected, one or more of the parameters measuring organic pollution (BOD, COD, 24-hr. Cl_2 Demand) showed increasing trends that supported the increasing trend in coliform levels at all stations. However, there was no single parameter that showed a consistent correlation with coliforms at all five stations. BOD values, although reflecting the bacterially degradable materials in a stream, do not correlate well with coliform values. Chlorine demand correlates fairly well with coliform values. This is understandable with the demand measuring a broader portion of the total organic load. Its reaction was quite similar in direction and sensitivity to the COD measurement.

COD trends agree more closely than BOD with coliform trends, possibly because of a common correlation with flow. It has been found in a study of Missouri River water quality that COD is strongly dependent upon suspended solids concentration. Thus, increased suspended loads produce a higher COD. Similarly, as stream flows increase, land run-off, combined sewer overflows and treatment plant bypassing of raw sewage result in higher coliform densities during the rising hydrograph. However, as high flows continue beyond a day or two, simple dilution begins to exert a reducing effect on the coliform density.

As stream flows decrease, a series of complex relationships are brought into play. Lower flows result in greater concentrations of soluble materials, settling out of solids, increased daytime temperature with shallower depths, decreased turbidity, and increased algae development. COD values may be increased or decreased with this reduced stream flow.

Phosphate values do not show any marked correlation with coliform increases. Although phosphate concentrations are increasing on a nation wide basis because of increased population, and detergent product usage, the picture is complicated by phosphate exchange between the algae and bacteria in a stream.

There was a lack of good correlation of the percent oxygen saturation values with the coliform values. With percent saturation values

measuring a minimum of 65 - 70% at these specific points, it would suggest that the oxygen reserve was sufficient to carry the bacterial load, or with the more polluted points was above or below the oxygen sag exerted by the wastes.

In summary, coliform bacteria and other pollution indices varied in a generally consistent manner at any one station. Different relationships were found to obtain at different stations.

Increasing Coliform Concentrations in New York Harbor

It is suggested that the increases in coliform bacteria in waters of New York Harbor which were observed during a period when sewage treatment facilities were being increased are due to the changed behavior of suspended solids in the effluents. This phenomenon was studied in Santa Monica Bay in connection with the expansion of the City of Los Angeles' Hyperion Treatment Plant[1]. Here it was determined from field observations that suspended solids in primary effluent settled with a rate coefficient of 4 times that for secondary effluent. The coliforms associated with the solids were, of course, similarly affected. It should be noted that this work was done with unchlorinated effluent.

Although the initial coliform concentrations were over three times higher in the primary effluent, they were removed from the

surface waters much more rapidly. After about 3-1/2 hours, the remaining concentrations were the same. After 12 and 24 hours, coliforms from secondary effluent were about 14X and 720X, respectively, the concentrations resulting from primary effluent.

The differential settling rates which were found in Santa Monica Bay are readily explained by the reasonable assumption that the suspended particles in secondary effluent are smaller, though perhaps not significantly fewer in number, than those in primary effluent. In any event, primary effluent solids were more amenable to coagulation and sedimentation in the ocean.

These results were subsequently confirmed in the laboratory[2]. The time and money available did not permit developing quantitative relationships between the laboratory and field observations. Nevertheless, the work did indicate that techniques could be developed which would permit prediction of the effects of flocculation and sedimentation upon coliforms in salt waters.

The Santa Monica Bay work was based on a comparison of primary and secondary effluent. As a first approximation, it is reasonable to assume that similar differences obtain between raw sewage and primary effluent.

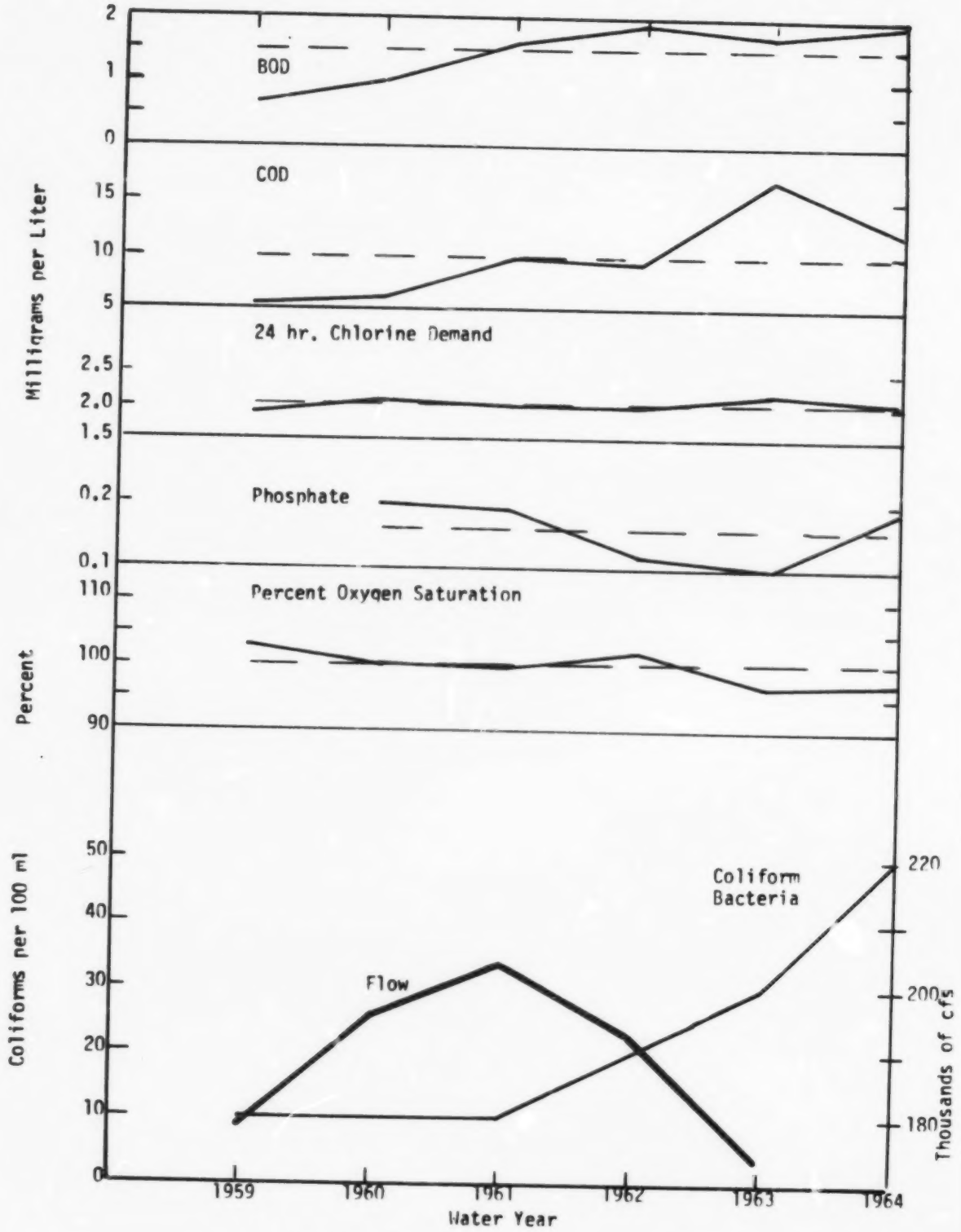
The suggestion that increases in coliform bacteria in New York Harbor waters are a direct result of improved treatment practice can

be readily investigated from a qualitative point of view. Either the field or laboratory methods employed at Hyperion can be used. There is also a good chance that analysis of the available field data from the harbor, with particular attention to probable age of the effluent and the salinity, will be fruitful.

References

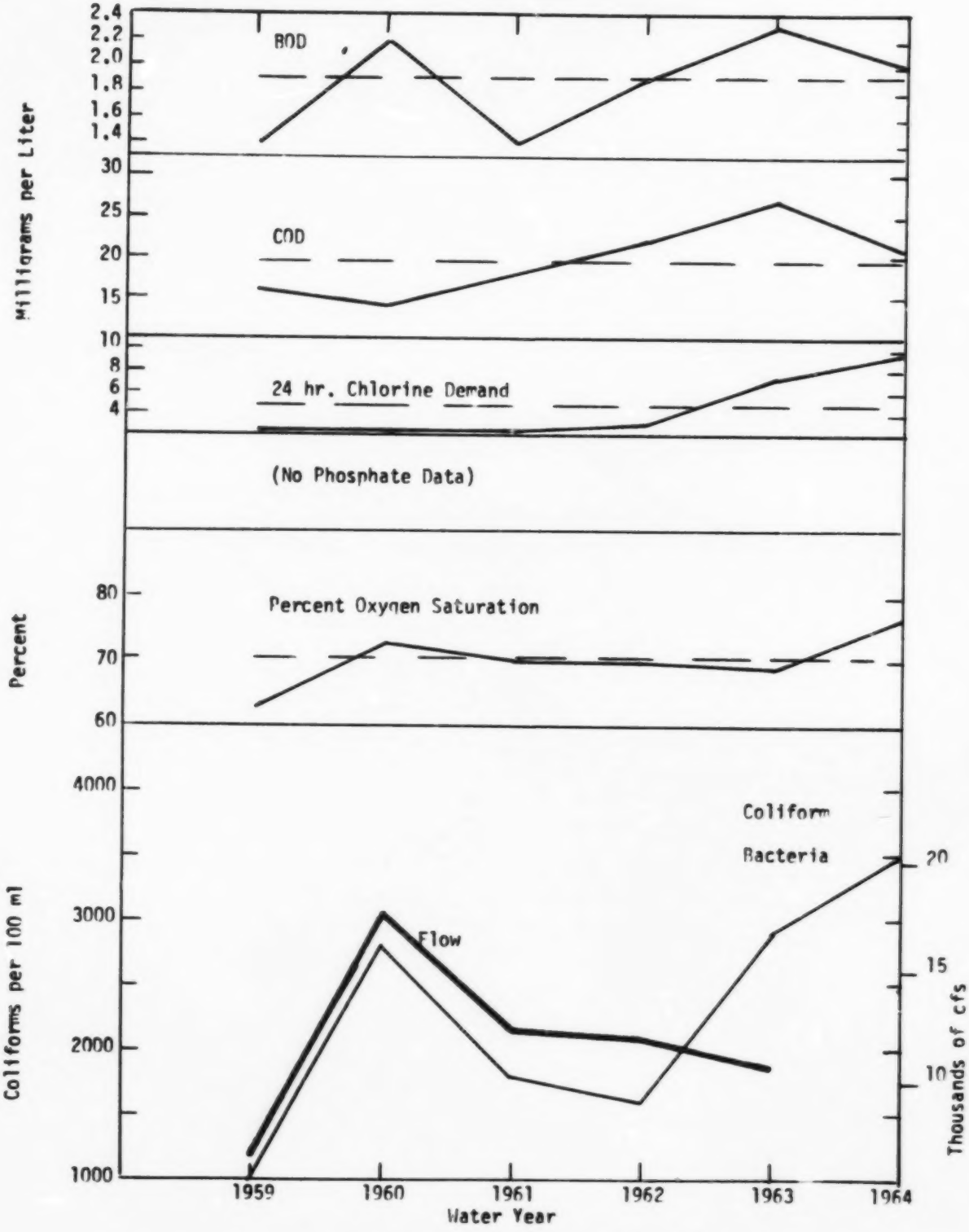
(1) Gunnerson, C. G. "Sewage Disposal in Santa Monica Bay." Trans. ASCE, Vol. 124, pp. 823-851 (1959).

(2) Gunnerson, C. G. "Discussion of The Settling Properties of Suspensions." Proc. ASCE, Vol. 86, No. HY7, pp. 29-32 (1960).



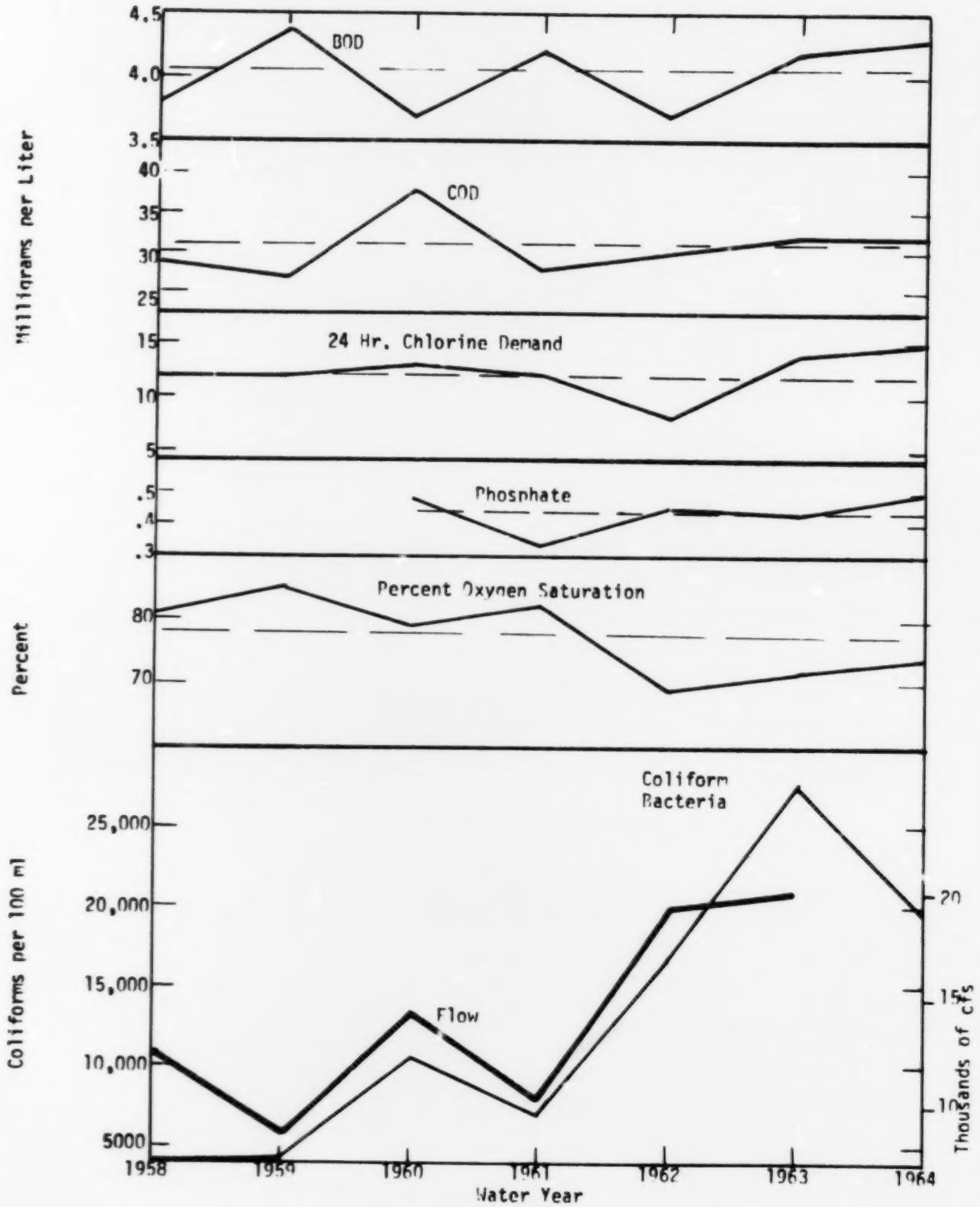
AVERAGE WATER QUALITY CHARACTERISTICS

Lake Erie at Buffalo (WPSS Station 14)



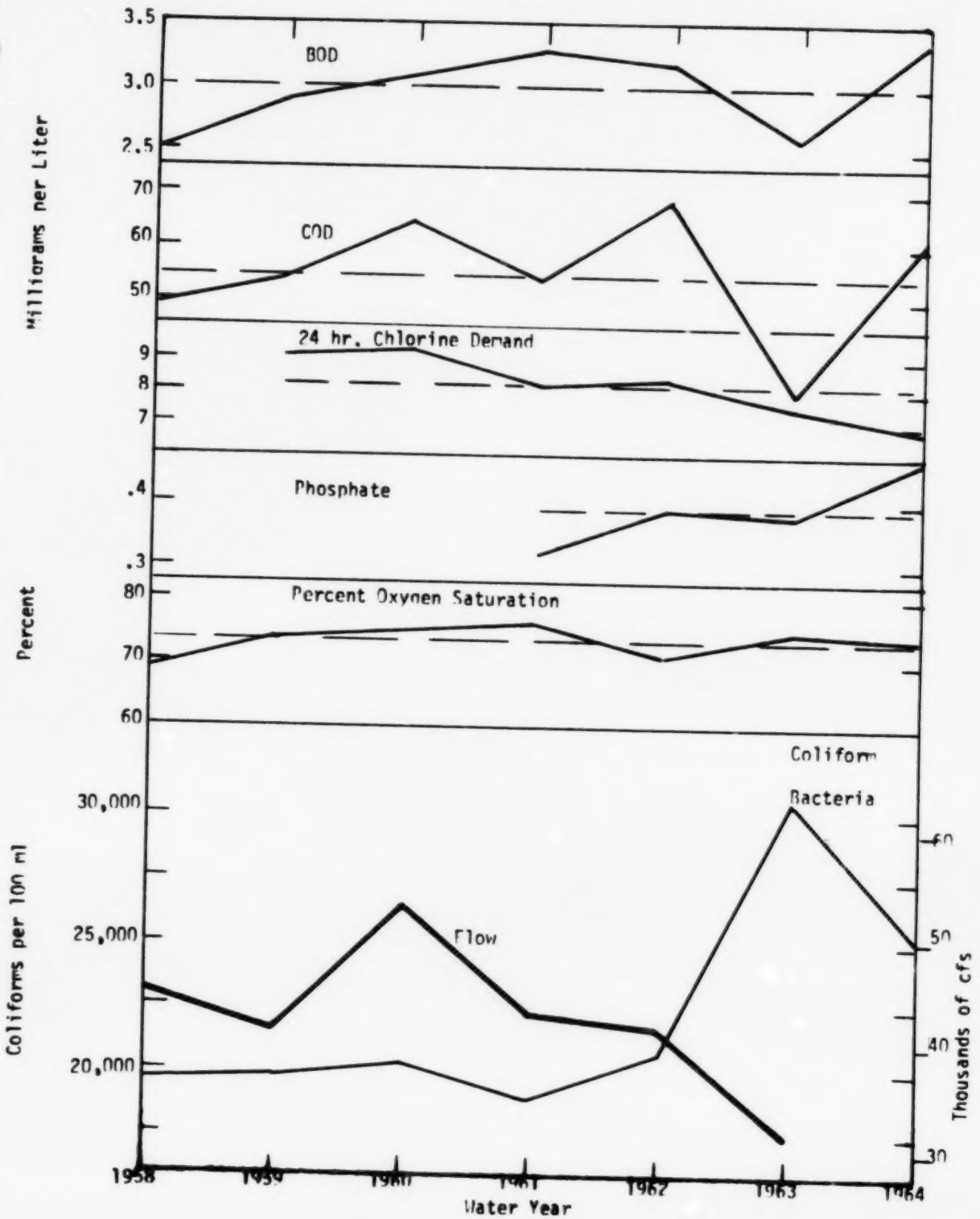
AVERAGE WATER QUALITY CHARACTERISTICS

Hudson River below Poughkeepsie, New York (WPSS Station 18)



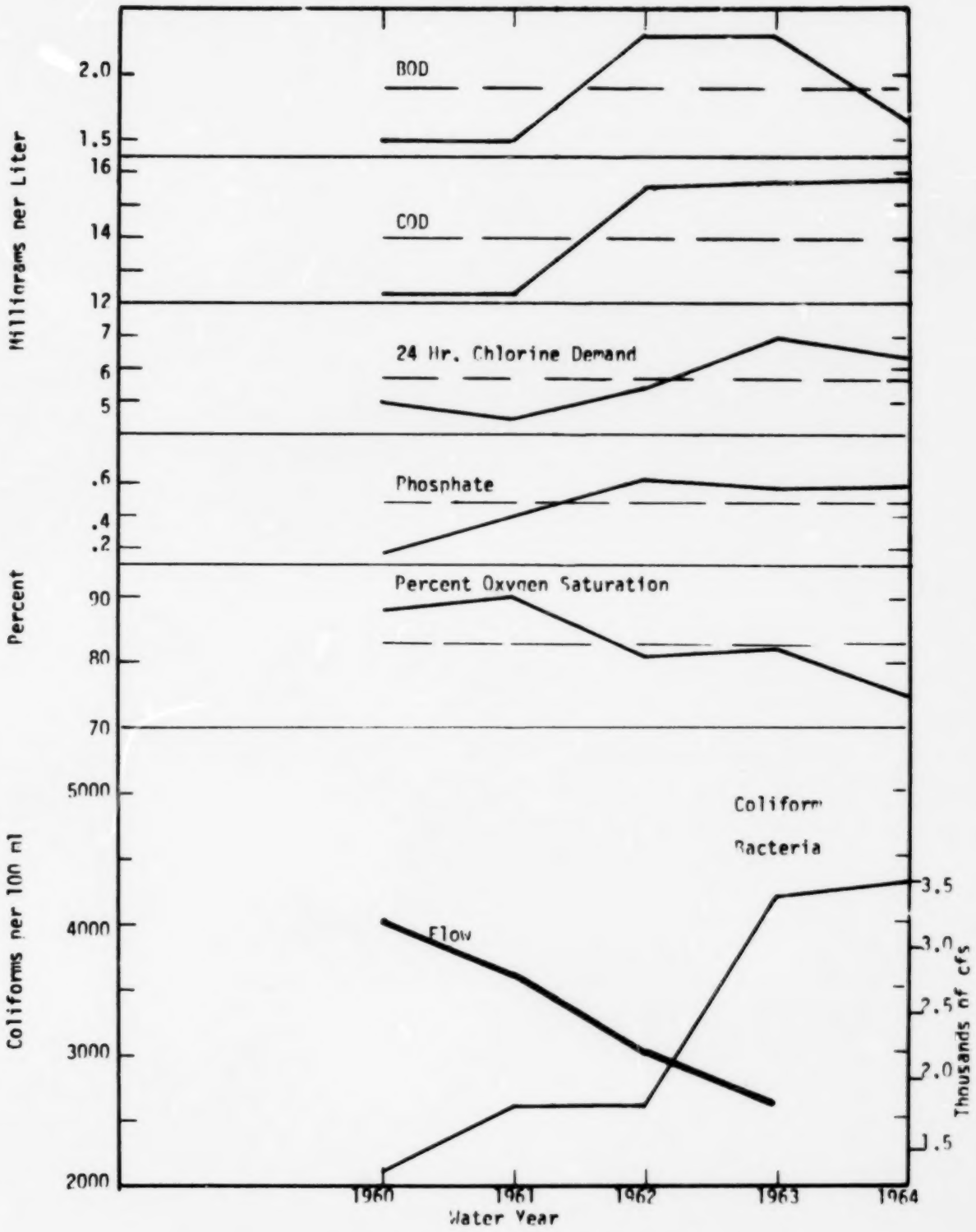
AVERAGE WATER QUALITY CHARACTERISTICS

Mississippi River at Lock & Dam #3 Below St. Paul, Minn. (WPSS Sta. 27)



AVERAGE WATER QUALITY CHARACTERISTICS

Missouri River at Kansas City, Kansas (MPSS Station 29)



AVERAGE WATER QUALITY CHARACTERISTICS
Schuylkill River at Philadelphia, Pa. (WPSS Station 74)